AIRS Tropospheric CO_2 and (Upper-Trop) CH_4 retrievals.

Breno Imbiriba, Larrabee Strow, Sergio de Souza-Machado, and Scott Hannon.

Atmospheric Spectroscopy Laboratory (ASL)
University of Maryland Baltimore County Physics Department
and the
Joint Center for Earth Systems Technology

AIRS Science Team Meeting - Greenbelt, MD
October 14, 2008

ASL

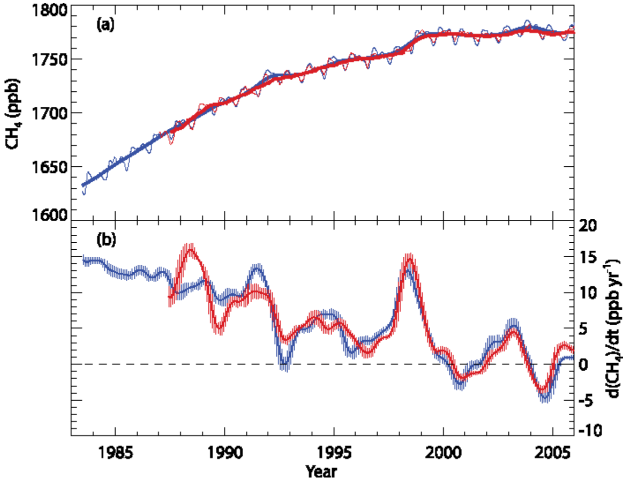
Overview

- Interested in measuring CO_2 and CH_4 with AIRS/IASI/CrIS
- Primary interest is rates, for monitoring growth of greenhouse forcing gases
- Using simple techniques to get rates quickly. AIRS CDS is data source (mostly), so no CC'd data used.
- We use ECMWF temperature fields, and ...
- Internal diagnostics show ECMWF temperature fields (for troposphere) are good enough.
- 4-year CO_2 climatology published in JGR in Sept. 2008
- This presentation:
  - CH_4 growth rates
  - Comparison of 4-year CO_2 climatology to NOAA CarbonTracker (CT)
  - Progress in CO_2 retrievals (300-600 mbar range) over land, esp. with regard to cloud filtering

ASL Use of ECMWF

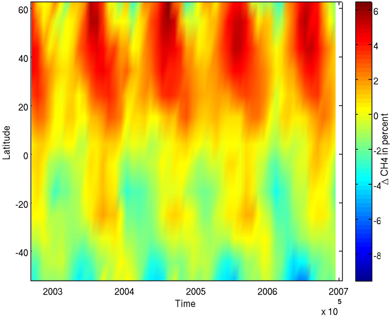
- ECMWF uses radiosonde measurements as the "anchoring network" of observations for the ECMWF tropospheric temperatures with no bias correction, see Auligne, T., A. McNally, and D. Dee (2007), Adaptive bias correction for satellite data in a numerical weather prediction system, QJRMS, *133*, 631–642, doi10.1002/qj.56.
- ECWMF $T(z)$ fields are essentially optimially interpolated radiosondes, AIRS/IASI radiances are bias-adjusted to agree with radiosondes
- Bias of AIRS vs ECMWF has a standard deviation in CO_2 channels at the AIRS noise level - before and after assimilation of AIRS at ECMWF.
- 4-year CO_2 growth rates derived from AIRS biases relative to ECMWF gives 2.2 ppm/year $\pm$0.2 ppm/year, compared to MLO in-situ rate of 2.05 ppm/year. This difference corresponds to 5mK/year difference in BT units.

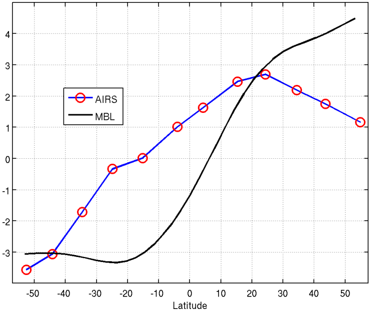
CH_4: IPCC Report Shows Growth Slowing



CH_4 Climatology

- One CH_4 channel used: 1303.2 cm^{-1}
- One CO_2 line (with similar dBT/dT to 1303.3 cm^{-1} CH_4 line) used to correct for variability in ECMWF upper-trop temperatures).
- dBT/dCH4 peaks ~300 mbar

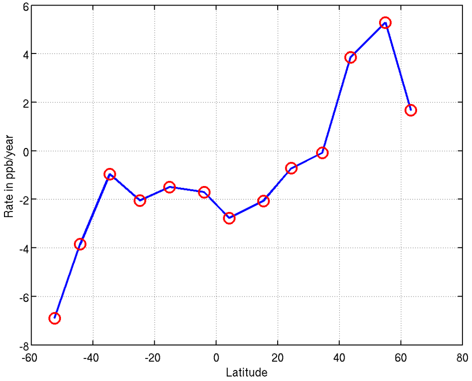




ASL

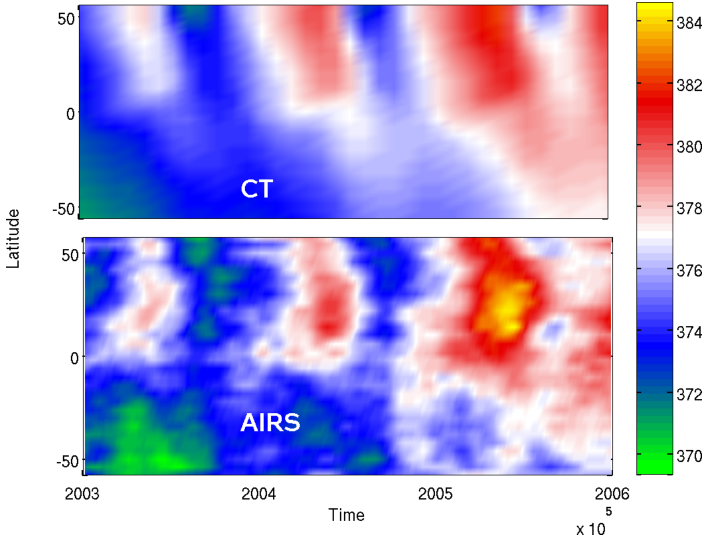
CH_4 Growth Rates

- Growth rate measured as a function of latitude
- 36 month growth rate = 0.90 $\pm$ 3.9 ppb/year
- 48 month growth rate = -1.1 $\pm$ 3.2 ppm/year
- Comparable to IPCC published rates, much lower than $\sim$15 ppm/year growth rates in the 70's and 80's.



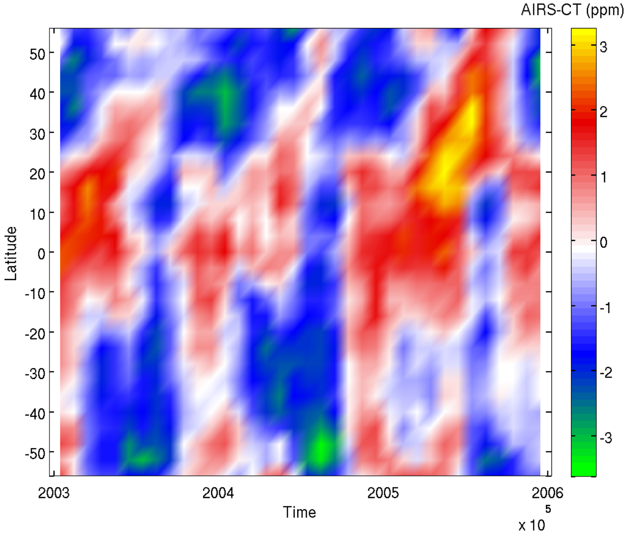
AIRS vs. CarbonTracker

CT Convolved with $(dBT/dCO_2)_L$

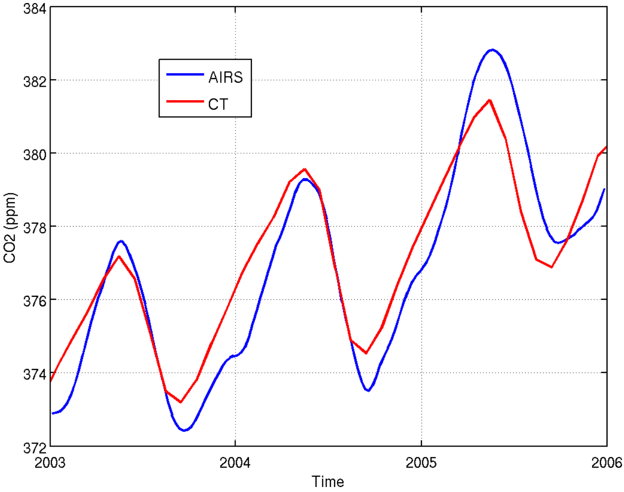


ASL

AIRS Minus CarbonTracker

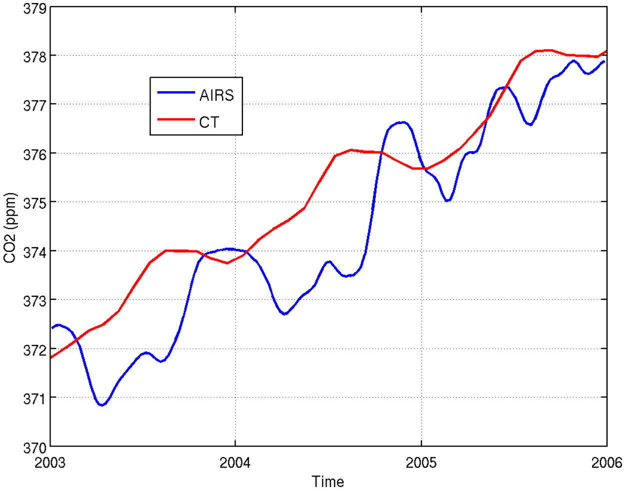


AIRS vs. CarbonTracker: Avg. of 20N to 50N



ASL

AIRS vs. CarbonTracker: Avg. of 20S to 50S

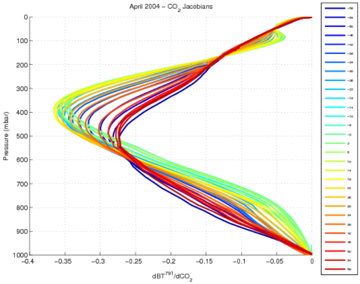


Conclusions: AIRS Ocean CO_2 vs CarbonTracker (CT)

- General agreement between AIRS and CT
- AIRS tropical CO_2 cycle more intense
- In NH, CT CO_2 general grows more quickly, AIRS and CT decrease in summer months generally similar
- In SH winter, AIRS CO_2 lower than CT, otherwise similar
- AIRS may be key instrument for improving CO_2 transport models, but more validation needed.

CO_2 General Retrieval Approach

- Input is clear FOVS in AIRS CDS
- SW and LW approach, Used LW for ocean, but SW appears better over land
  - Use channels sensitive to mid tropospheric CO_2
  - Narrow "Q branch" ν_2 transition at $791.75 cm^{-1}$ (LW)
  - Broad "R branch" ν_3 transition around $2387 - 2390 cm^{-1}$ (SW).
- Peak at 450mbar (Mid-Troposphere) $\approx$ 6.7Km. Can be much lower over land in tropics.



Retrieval Steps

- Assume ECMWF has good temperature profile (*unbiased*).
- Correct for surface temperature and overall water content.
- In each band, solve for CO_2 and T_s.
- For example LW:
  - $790 cm^{-1}$ (no sensitivity to CO_2)
  - $791 cm^{-1}$ (right on a CO_2 line).

$$
\begin{aligned}
B^{790}_{obs} - B^{790}_{calc} &= J^{790}_{T_s} \delta T_s \\
B^{791}_{obs} - B^{791}_{calc} &= J^{791}_{T_s} \delta T_s + J^{791}_{T_{CO_2}} \delta CO_2
\end{aligned}
$$

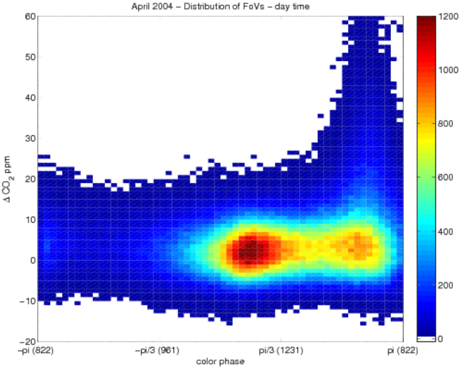
- Emissivity errors (and others) go into the “effective” T_s. Corrections are applied on sensitive channels
- Also accounts for very low clouds (below the sensitivity of the weighting function).

New Steps to Approach ppm Level CO_2 Retrievals over Land

- Cloud contamination is key issue, especially cirrus
- Detection of clouds more difficult over land
- Will present new cloud flag concept
- Retrieved CO_2 depends on secant angle due to RTA errors (up to 6 ppm max)
- Methodology to correct RTA errors (calibration) does not require external calibration data
- Will show comparisons to CarbonTracker for three months

Land CO_2 Complicated by Cloud Contamination

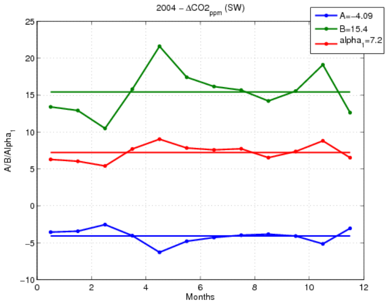
- Empirically based cloud flag being tested. Uses ECMWF *atmospheric fields* to determine best cloud flag.
- Compute three **biases** across thermal window: 822 cm^{-1} (cirrus), 961 cm^{-1} (2616 cm^{-1}), 1231 cm^{-1}. Combine as RGB.
- $\tan(h) = \frac{\sqrt{3}}{2}\frac{G-B}{R-G-B}$ is X-axis, Y-axis is CO_2, color is FOV count



Satellite Zenith Angle Correction

Assumes ECMWF Error independent of zenith angle

- RTA spectroscopy errors will accumulate acording to the *secant of satellite zenith angle*.
- CO_2 versus $\sec\theta_{sz}$ fit to a quadratic function: $CO_2 = A\sec^2\theta_{sz} + B\sec\theta_{sz} + C$.
- Will adjust CO_2 ppm according to: $CO_2{}^{new} = CO_2 - A(\sec^2\theta_{sz} - 1) - B(\sec\theta_{sz} - 1)$.
- Note: nadir needs ~8 ppm spectroscopy correction (alpha)

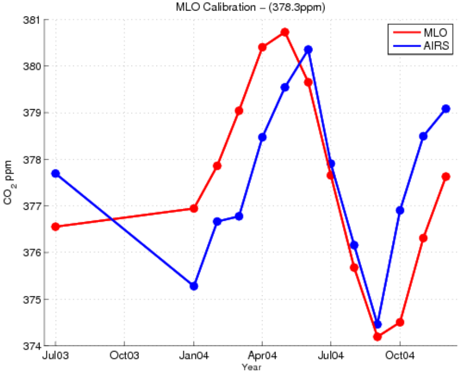


ASL

Mauna Loa Calibration

Shown after 8 ppm correction

8 ppm correction same as correction derived from zenith angle bias!



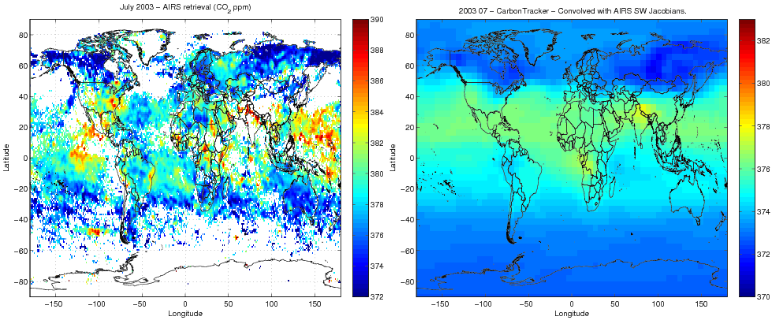
- 5 deg box around the island - Fit for the 2004 annual mean.

ASL

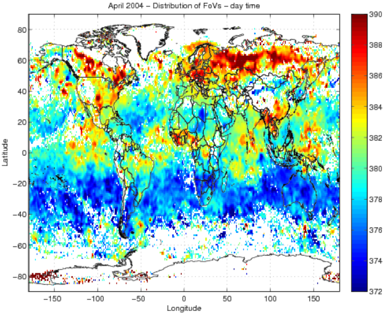
Comparison of Land CO_2 to CT for Several Months

- Results clearly show seasonal patterns.
- Over Ocean - reasonably confident, validated.
- Over Land - retrievals are $\sim$ 2-6 ppm higher than CT
- See more CO_2 structure over land than CT.
- Cloud filtering algorithms significantly improved.

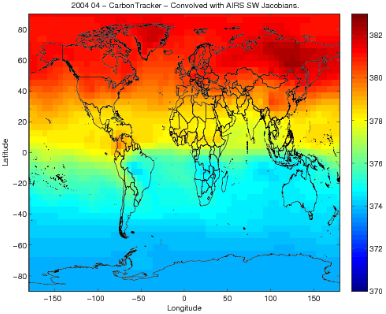
July 2003


July 2003 – AIRS retrieval (CO2 ppm)
Latitude
Longitude
2003 07 – CarbonTracker – Convolved with AIRS SW Jacobians.
Latitude
Longitude

April 2004

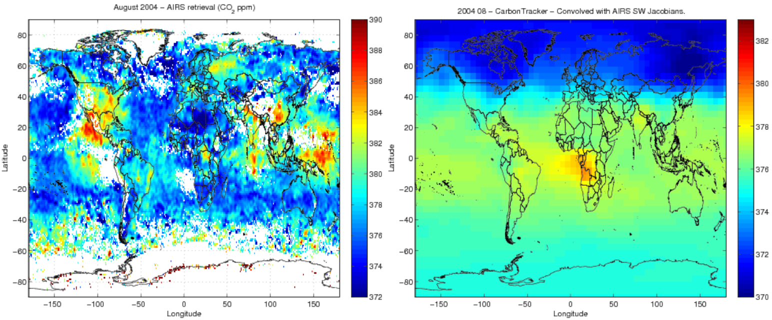


April 2004 – Distribution of FoVs – day time
Latitude
Longitude
80
60
40
20
0
−20
−40
−60
−80
−150
−100
−50
0
50
100
150
390
388
386
384
382
380
378
376
374
372



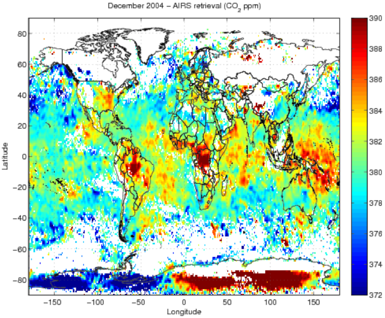
2004 04 – CarbonTracker – Convolved with AIRS SW Jacobians.
Latitude
Longitude
80
60
40
20
0
−20
−40
−60
−80
−150
−100
−50
0
50
100
150
382
380
378
376
374
372
370

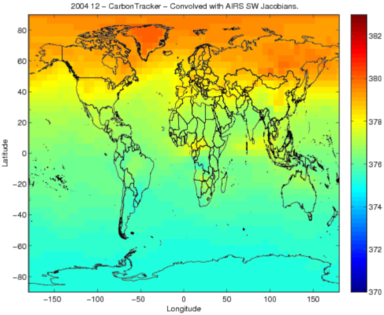
August 2004



August 2004 – AIRS retrieval (CO2 ppm)
Latitude
Longitude
2004 08 – CarbonTracker – Convolved with AIRS SW Jacobians.
Latitude
Longitude

December 2004





ASL Conclusions, Land CO_2 Retrievals

- Land CO_2 retrievals in the 400-550 mbar region are very sensitive to cloud contamination, cloud flag is improving
- May test algorithm on CC'd data.
- May have calibration correction that doesn't require external data for absolute accuracy (secant angle correction).
- Comparisons to CT are encouraging, but biased high.
- Need to process large amount of data in order to maximize number of coincidences with validation data.